# COST EFFECTIVE VV&A: FIVE PREREQUISITES

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## ABSTRACT

Recent requirements to establish the credibility of the models and simulations (M&S) that are used in Department of Defense (DoD) applications have resulted in the development of several approaches to M&S credibility assessment. Each of these approaches attempts to integrate verification and validation (V&V) activities into a formal process whose products (hopefully) support M&S accreditation. The cost of "VV&A" activities has not typically been a driving factor in the development of these processes, however, and their independent and fragmentary development has tended to result in "point-solution" approaches to the problem of cost-effectiveness. Despite their diversity, however, many VV&A processes share features in common, suggesting that it may be possible to identify the essential elements of cost-effective VV&A.

This paper proposes five "common sense" elements of cost-effective VV&A, and describes how each of these elements can contribute to the cost-effectiveness of VV&A processes in general. A comparative analysis of six VV&A processes currently in use to support M&S accreditation for a wide variety of DoD applications is then presented. The analysis reveals that the five elements proposed as essential to cost-effective VV&A do, in fact, characterize, in whole or in substantial part, all of the VV&A processes considered. The paper concludes by considering some of the evaluative implications of these findings.

## INTRODUCTION

Various elements of the M&S community have attempted to identify and define the technical and formal requirements for the accreditation of particular M&S types or particular classes of M&S applications, but there remains considerable concern over the cost of VV&A activities. Recent attempts at addressing the cost issue have focused primarily on reducing the number of dollars spent on VV&A, rather than on improving the "effectiveness" of those dollars that are spent. An optimum cost solution to the VV&A problem, however, must take into account two factors: 1) an objectively justifiable reduction in the number of activities that are performed (and thus the dollars spent), and 2) a logical selection of the most appropriate type of activities to perform, based on their contributions to M&S credibility relative to their typical cost. The challenge is to define what features of VV&A processes need to be present in order for optimum cost solutions to be feasible. This paper attempts to identify the elements of cost-effective VV&A, and to generalize these elements well enough for widespread application.

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## ELEMENTS OF COST-EFFECTIVENESS

In trying to define a robust set of factors that can be used to evaluate and improve the cost-effectiveness of VV&A processes, we need to make sure that the factors proposed are generic enough to be broadly applicable, and yet substantive enough to be technically useful in practical application. To develop a logical set of generic requirements for cost-effective VV&A, we might reason as follows:

"It stands to reason that cost savings in, and improved effectiveness of, VV&A must result from at least two factors: skillful focusing and tailoring of VV&A activities to meet objectively defined M&S requirements for specific applications; and reuse of prior VV&A information wherever possible. By analyzing the application at hand, and focusing and tailoring VV&A activities to meet objectively defined credibility requirements for any M&S that might be considered for use in the application, one can prevent superfluous activities from being conducted; and by reusing prior VV&A information wherever possible, one can avoid paying for information that is already available.

"But `focusing and tailoring' of VV&A activities would seem to require that there be some recognized and reliable way to choose the most appropriate activities from among those possible to perform, and, moreover, to tailor these activities to maximize relevance to the application at hand. In order for such a tailoring process to yield reliable cost savings and improved effectiveness, while still meeting the requirements of the application, two further prerequisites seem to be implied: the range of applications to which the tailoring process applies would have to be well-defined, as would some standard list of applicable VV&A activities, each of which is known to add well-defined and unique elements of credibility to M&S.

"Effective `reuse of VV&A information' would seem to require that VV&A techniques and procedures be defined and standardized for application to particular M&S types or to particular classes of M&S application; otherwise, there would be no way to ensure consistency of interpretation of VV&A results across the spectrum of possible M&S types and M&S applications. Since no one would be sure just what substantive information a particular type of VV&A report might contain, the attempted reuse of VV&A information would become too cumbersome to be effective. In addition, VV&A results would have to be reported in a standardized way, to minimize confusion, and to form the basis for an accumulation of evidence of M&S credibility over time. Finally, easy access to any prior VV&A information generated by the standard process and documented in the standard fashion would be essential to widespread reuse of standardized VV&A data sets for different types of M&S or different classes of M&S application."

If we summarize the requirements for cost-effective VV&A implicit in the above, we have:

1. A well-defined menu of VV&A activities, each of which provides a well-defined, unique (and community-recognized) contribution to M&S credibility;

2. A process for selecting VV&A activities from this menu based on requirements derived from detailed analysis of individual applications;

3. A well-defined (and documented) process for performing each of the VV&A activities;
4. A set of standards and guidelines for reporting (and accumulating) VV&A results, and;
5. A repository of readily accessible and easily retrievable prior VV&A results.

The following sections describe these "requirements" in detail, and discuss their potential contribution to the cost-effectiveness of VV&A.

## Menu of Activities

A VV&A menu is a list of activities, each of which produces explicitly defined technical information, and each of which contributes to M&S credibility in a unique way. Explicit definitions prevent confusion as to what is meant by each activity; a requirement for each activity to contribute uniquely to M&S credibility reduces technical overlap between ostensibly similar activities (or their products), as well as the tendency to duplication of effort.

A VV&A menu should consist of a list of possible activities, a concise technical description of each activity (including what tasks are required to complete that activity), a general description of the documentation product that should result from the activity, and a clear identification how the given activity contributes to M&S credibility. Insofar as possible, VV&A activities should be categorized and subdivided according to the type of information they provide, and groups of activities that form coherent subsets of critical information should be identified.

Since no single set of activities will be universally applicable to every type of M&S or to every class of M&S application, VV&A menus will tend to be focused on the unique requirements of the M&S communities for which they are developed. Tailored VV&A menus can help convert VV&A from a "black art", in which the technical definition and implementation of each activity is in the eye of the beholder, into a more cost-efficient and repeatable "science", in which modifications to basic techniques, which might be necessitated by the specifics of particular applications, proceed from a stable technical baseline.

## Tailoring Process

The importance of guidelines to assist M&S users in the task of optimizing VV&A activities and reducing VV&A costs cannot be overstated. Without a standard means of tailoring VV&A activities to the requirements of individual M&S or M&S applications, there will be a tendency to perform every activity on the menu, in the hopes of "proving" (through sheer volume, presumably) that the subject M&S have no discernible deficiencies. The "good" becomes the enemy of the "best", leading to the performance of unnecessary or objectively unjustifiable VV&A activities. The end result is a reinforcement of the perception (prevalent today) that VV&A "costs too much and takes too long", as well as the dilution of objective requirements for accreditation simply to meet a fixed (usually meager) VV&A budget. If an objective basis upon which to establish M&S credibility is a goal, a process to select and tailor VV&A activities in a way that meets objectively defined accreditation requirements at minimum cost is essential.

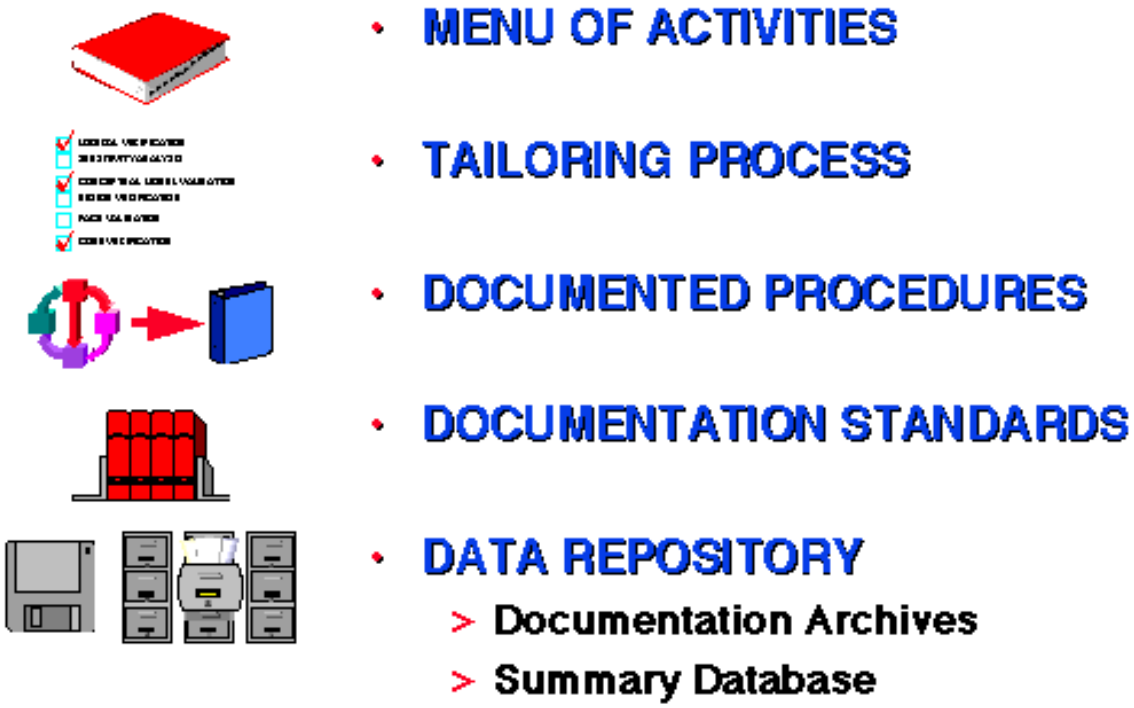


**Figure 1: Summary of Prerequisites to Cost-Effective VV&A**

To enhance cost-effectiveness, the VV&A task selection and tailoring process should address the tailoring problem from two points of view. The first aspect of the tailoring process should provide a means of identifying and prioritizing the M&S functional and fidelity requirements of the application, and relating these requirements to the most appropriate set of V&V activities, regardless of cost. The second aspect of the tailoring process should assign weights related to informative "value" to each proposed activity based on historical (or anecdotal) data, and should result in that mix of VV&A activities for each required M&S function that maximizes credibility while minimizing cost. It is interesting to note that these "weights" can be more easily assigned once the substantive contribution of each activity is well defined and understood, as above.

## Documented Procedures

A cost-effective VV&A process should include detailed, documented procedures for performing each of the tasks contained in the VV&A menu. Well-defined and documented procedures are important for three reasons: first, they contribute to a better understanding of the purpose of each activity, reducing confusion and encouraging consensus about the value of each; second, they aid the M&S user in planning and executing a tailored VV&A effort by forming a sound technical basis for excursions from the task baseline, as well by allowing a history of cost and schedule data associated with each activity to be developed, and; third, they improve the efficiency of task execution by reducing guesswork, focusing technical questions and developing a detailed and nuanced corporate memory and expertise in each task area.

VV&A activities should be integrated with appropriate aspects of the M&S development and configuration management processes wherever possible, so that M&S capability does not get out

of step with M&S credibility. Integration of VV&A with M&S development and configuration management allows VV&A information to be related to specific M&S versions, and establishes a VV&A "pedigree" that can be used to substantiate the credibility of unchanged portions of the M&S as later versions are developed.

Documents that describe VV&A activities should lay out VV&A procedures and techniques in a logical, incremental sequence wherever possible, so that the products of earlier activities can be used to accomplish later activities, reducing duplication of effort. This is especially important where multiple and diverse participants in the VV&A effort may be involved.

## Documentation Standards

Cost avoidance in VV&A is directly dependent on the availability (and utility) of prior results. Without the ability to reuse VV&A information, each M&S user is forced to perform VV&A independently, resulting in a strong tendency toward duplicative efforts. The usefulness of prior VV&A information, however, depends, in large part, on documentation standards that reduce or eliminate the problem of having to "interpret" the results of VV&A activities performed and reported by others in different ways. Moreover, documentation standards form a convenient basis for the accumulation of VV&A information over time.

The term "standards" refers to standardized information content and organization, not printing guidelines (e.g., margin size, font type and size, footnote and heading conventions, etc.), although these latter can certainly help the readability and ease of use of VV&A documentation. Some examples of standard types of VV&A information might be:

- Identification of the M&S version on which the VV&A activity was performed
- Description of the VV&A activity itself, especially any excursions from the accepted technical baseline definition of the activity
- Description of the results of the VV&A activity
- ID of any M&S limitations that follow from the results of the particular VV&A activity
- Impacts on M&S usage for the specific application that are implied by the results of the VV&A activity

## Data Repository

Documentation standards are insufficient, by themselves, to allow reuse of VV&A information on a wide scale. VV&A results must also be readily accessible to M&S users. This means that VV&A information must be archived and indexed in such a way that it can be easily located, extracted and distributed to typical M&S users. A database of summary results explicitly linked to the activities contained in the VV&A menu can also serve as a powerful M&S selection tool in cases where multiple M&S are under consideration for use in a given application. Such an archive can be used to filter M&S from among competing alternatives based on their defined functional capabilities and VV&A histories, and to identify VV&A activities already performed. This reduces the tendency to repeat activities, and can serve to focus the M&S community's attention on gaps in the composite VV&A record. As VV&A data gaps are filled over time by

M&S users, the entire M&S community benefits from the use of common VV&A data resources.

## PREVALENCE OF THE ELEMENTS

At this point, one might reasonably ask for evidence that the elements proposed as essential to cost-effective VV&A comprise a robust (and relevant) listing. To answer this question, we conducted a review of six major VV&A processes across DoD in the hopes determining whether or not any of the proposed elements of cost-effectiveness were widely used in actual practice. We anticipated three possible outcomes from such a review:

Outcome 1: The proposed features of cost-effective VV&A would be evident (in some form) in all or most of the existing VV&A processes examined. In this case, since the processes chosen for analysis were developed independently for a wide variety of M&S types and M&S applications, we would conclude that the features proposed as essential to cost-effective VV&A are somehow truly essential, or normative.

Outcome 2: None (or very few) of the proposed features of cost-effective VV&A would be found (in any form) in any of the VV&A processes examined, but other features of these VV&A processes might be similar to each other, and be related to cost-effectiveness. In this case we would conclude that we were barking up the wrong tree with our prescription for cost-effective VV&A, and that the existence of common features of VV&A processes other than we had proposed as essential to cost-effectiveness would imply that these (new) features should be the ones abstracted and generalized for use by the larger M&S community.

Outcome 3: There would be no correlation between our proposed features of cost-effective VV&A and actual VV&A processes, and no truly common features among the VV&A processes themselves. In this case, we would conclude that VV&A process development might be too closely linked to the type of M&S or M&S application to result in common features that could be generically related to the cost-effectiveness of VV&A.

Six VV&A processes were the subject of comparison and analysis, each of which is widely used (or accepted as normative) within the DoD M&S community that it serves:

- The VV&A process used by the Aggregate Level Simulation Protocol (ALSP) Program for use on the Joint Training Confederation (JTC).
- The Analyst Tool Box (ATB) M&S assessment process developed by the Ballistic Missile Defense Organization (BMDO).
- The 9-Step VV&A Process used by the Distributed Interactive Simulation (DIS) Program.
- The VV&A process used by the Joint Modeling and Simulation System (J-MASS) for component threat simulations.
- The VV&A process developed by the Military Operations Research Society (MORS) during its Simulation Validation (SIMVAL) Workshop series.

- The VV&A process developed by the Susceptibility Model Assessment with Range Test (SMART) Project for M&S used in airborne weapon system acquisition and testing.

| VV&A PROCESS ELEMENT | ALSP | ATB | DIS | J-MASS | MORS | SMART |
|---|---|---|---|---|---|---|
| Menu of Activities | I | I/D | I/D | I/D | D | I/D |
| Tailoring Process | I | I | I/D | | D | I/D |
| Documented Procedures | I/D | I/D | I | I/D | | I/D |
| Documentation Standards | | | | | D | I/D |
| Data Repository | I | D | D | I/D | D | I/D |

**Table 1: Matrix of V&V Processes and Attributes**

The results of the analysis are shown in table 1. In this table the letter "D" indicates that a requirement for the specified VV&A process feature is formally documented, but not implemented (for a variety of reasons) in practice. (See the authors' paper mentioned in footnote reference 6 for more details). The letter "I" indicates that the process feature is implicitly or explicitly implemented in the VV&A process considered.

Table 1 shows that two of the five features proposed as essential to cost-effective VV&A are exhibited by all of the processes examined. These are:

- A well-defined menu of VV&A activities, each of which has a clearly defined and well-accepted relationship to M&S credibility, and;
- A requirement for (or the existence of) a repository of prior VV&A data that is readily accessible to M&S users.

Two of the features proposed as essential to cost-effective VV&A were exhibited by five of the six VV&A processes examined. These are:

- A VV&A activity selection and tailoring process that translates M&S application requirements into VV&A requirements, and;
- A set of documented procedures for VV&A techniques and procedures that provides both technical details and a discussion of expected product.

The feature "common reporting standards" was addressed only by the MORS and SMART VV&A processes. A recent review of the ALSP methodology, however, resulted in a recommendation that common reporting standards be adopted. This recommendation was favorably received by the ALSP Program Office and may be reflected in future Accreditation Reports produced by that program. The development of the DIS 9-Step VV&A process did not

originally consider the benefits of common reporting standards. Recent interactions with the SMART Project via the Defense Modeling and Simulation Office (DMSO), however, have resulted in endorsement at least of the concept, as well as discussions related to incorporating it into the DIS approach to VV&A.

## CONCLUSIONS

We admit that it has not been established, either logically or empirically, that the five attributes proposed as essential to cost-effective VV&A are sufficient (in a formal logical sense) to guarantee the cost-effectiveness of a VV&A process. There may be other attributes that contribute to cost-effectiveness, or it could be that other, unconsidered, factors mitigate against cost-effectiveness even when the features considered here are present. On the basis of their near-ubiquitous presence in VV&A processes that were independently designed for different M&S types and applications, however, it seems reasonable to conclude that these attributes are, at least, "necessary" in the logical sense. The most prominent, well-accepted and widely used VV&A processes just seem to possess these features in some form or another. As a result, it seems reasonable to consider these features normative for purposes of developing or evaluating VV&A processes for new M&S types or classes of applications. Moreover, it is reasonable to propose these features as the ones for which the DoD should provide some means of centralized support, to encourage their development for, and consistent application to, the many types of M&S and M&S applications which come under the purview of DoD M&S interests. In the interim, the features proposed here can be used to evaluate or modify existing VV&A processes by using them to identify current process features where the most improvement in cost-effectiveness can be made.

## *ABOUT THE AUTHORS*

Dr. Muessig received his B.S. in Chemistry in 1981 from St. Joseph's University in Philadelphia, and was awarded the doctorate in Physical Chemistry from Brown University in 1987. He began his career as a defense analyst at the Center for Naval Analyses in Alexandria, VA, working on technical feasibility assessments of advanced technology aircraft using M&S. While there he coordinated two separate validation efforts for the Advanced Low Altitude Radar Model (ALARM). He later became CNA's field representative to the Naval Strike Warfare Center in Fallon NV, contributing to the training syllabus in strike warfare, conducting tactical analyses and coordinating Tactics Development and Evaluation projects.

Dr. Muessig joined the Naval Air Warfare Center, Weapons Division at China Lake, CA in 1989 (then the Naval Weapons Center), working on a project to integrate data collected from strike training exercises to validate survivability assessment methodologies. It was during this time that the idea for SMART began to take shape. A proposal to the Office of the Secretary of Defense (OSD) to develop and test an integrated M&S credibility assessment process utilizing field test data was developed, approved and funded in FY92. Since that time, Dr. Muessig has acted as Deputy Project Manager and Technical Director for the SMART Project. He is the author of numerous technical publications, most dealing with the validation of survivability M&S using

test data, V&V process development, and V&V application strategies to support M&S accreditation. He is also editor of the SMART Project newsletter, SMARTALK.

Mr. Laack is a retired combat Naval Aviator with extensive experience in directing and managing research, development, acquisition, and testing of naval aircraft, weapons and related systems. For the five years he has provided management and technical assistance to the Joint Accreditation Support Activity (JASA), including original contributions in the areas of accreditation requirements determination, M&S acceptance criteria development, and V&V requirements derivation. Mr. Laack holds a B.E.E. from Marquette University, and M.S. in Systems Acquisition Management, and both an M.S. and an Ae.E. in Aeronautical Engineering from the Naval Postgraduate School. He is employed by Computer Sciences Corporation in Camarillo, California.